Space Technology Research Grants

Direct Generation of Oxygen via Electrocatalytic Reduction of Carbon Dioxide in an Ionic Liquid

Completed Technology Project (2014 - 2018)

Project Introduction

In a space habitat, air revitalization is a necessary function for maintaining a safe and breathable atmosphere for humans. This functionality includes removing carbon dioxide (CO_2) and trace contaminants (TCs), providing oxygen (O_2) and nitrogen (N_2) makeup gases, and controlling the humidity. In an open-loop environmental control and life support system (ECLSS), CO_2 and TCs are vented out of the space habitat, while O_2 and N_2 are supplied by regular resupply missions. For long duration missions, closing the ECLSS consumables loop has potential to reduce the costs associated with resupply missions by decreasing their frequency and the consumable mass they are required to bring. For future missions with target destinations of asteroids, the moon, and Mars, consumable resupply missions would be logistically difficult, if not impossible. As such, recycling all materials on-board a spacecraft becomes a critical, mission enabling functionality. With respect to air revitalization, consumable recycling largely amounts to reducing CO_2 to yield O_2. This same process may also be useful for in-situ resource utilization (ISRU) on Mars by reducing atmospheric CO_2 to supply a habitat with O_2 and propellant. This research proposes to investigate the direct generation of O_2 via the reduction of CO_2 in an electrochemical cell utilizing an ionic liquid (IL) catalyst. The current method to reduce CO_2 aboard the space station is the Sabatier process. This process reacts hydrogen with CO_2 at high temperature and pressure to produce methane and water. In order to get O_2 from the reduced CO_2, the water produced from the Sabatier process is electrolyzed, splitting it into hydrogen and oxygen. Currently, there is no implemented system that utilizes methane space station so this resource is vented to space, resulting in a loss of both carbon and hydrogen. Disadvantages of this current state of the art for CO_2 reduction and O_2 generation in a spacecraft are requirements for high temperature, pressure, and power usage with a significant amount of system complexity to support the processes. Electrochemically reducing CO_2 is normally a very energy intensive process. However, ILs have properties that let them act as both CO_2 absorbers and reduction catalysts, effectively decreasing the required energy to recycle CO_2. By enabling reduction of CO_2 directly to the products of O_2 and carbon monoxide (CO), this process eliminates the need to provide hydrogen as feedstock and the need for a separate water electrolysis system to split water into hydrogen and oxygen. Because there are a vast number of potential cation-anion pairs that can be made to form ILs, and because ILs can be expensive and difficult to synthesize, a means of predicting IL properties prior to synthesis would be extremely valuable. This research aims to investigate the properties of ILs based modeling the molecular structure of their cation-anion pairs. ILs that are determined to have favorable properties to CO_2 reduction and O_2 generation will be studied with respect to their intrinsic properties, as well as their operation through a range of environmental conditions. Improving efficiency and scalability of this electrocatalytic reduction via IL selection and electrochemical cell design are the ultimate goals of this research. While this work will advance technology that can

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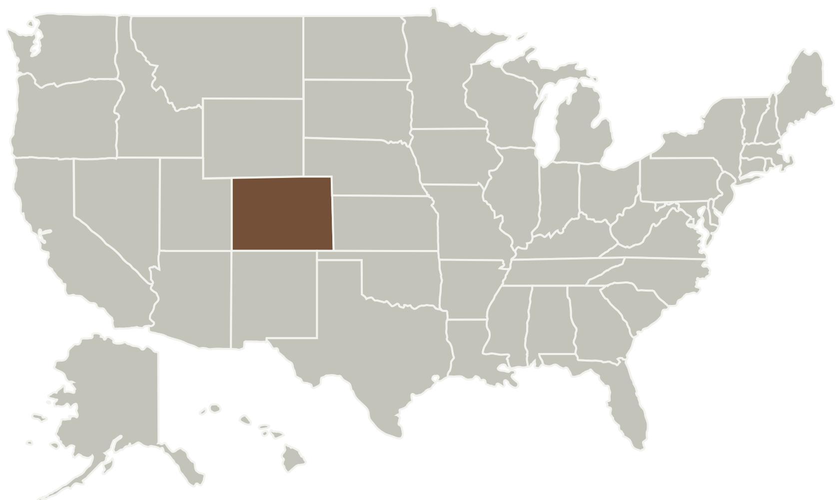
improve upon the current state of the art for CO2 reduction and O2 generation in a spacecraft, it can also be prove beneficial to the energy production industry and to the environment. If electrocatalytic reduction of CO2 can become commercially viable, it will create a new avenue for producing renewable energy and it has the potential to reduce the impact of energy production on the environment.

Anticipated Benefits

While this work will advance technology that can improve upon the current state of the art for CO2 reduction and O2 generation in a spacecraft, it can also be prove beneficial to the energy production industry and to the environment. If electrocatalytic reduction of CO2 can become commercially viable, it will create a new avenue for producing renewable energy and it has the potential to reduce the impact of energy production on the environment.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Colorado Boulder	Lead Organization	Academia	Boulder, Colorado

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Colorado Boulder

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

David Klaus

Co-Investigator:

Jordan B Holquist

Primary U.S. Work Locations

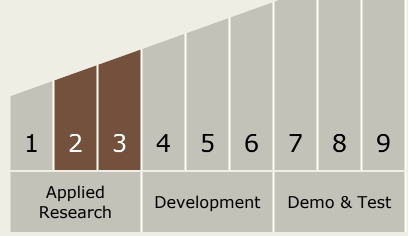
Colorado

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX07 Exploration Destination Systems
  - └─ TX07.1 In-Situ Resource Utilization
    - └─ TX07.1.3 Resource Processing for Production of Mission Consumables

Target Destinations

Earth, The Moon, Mars